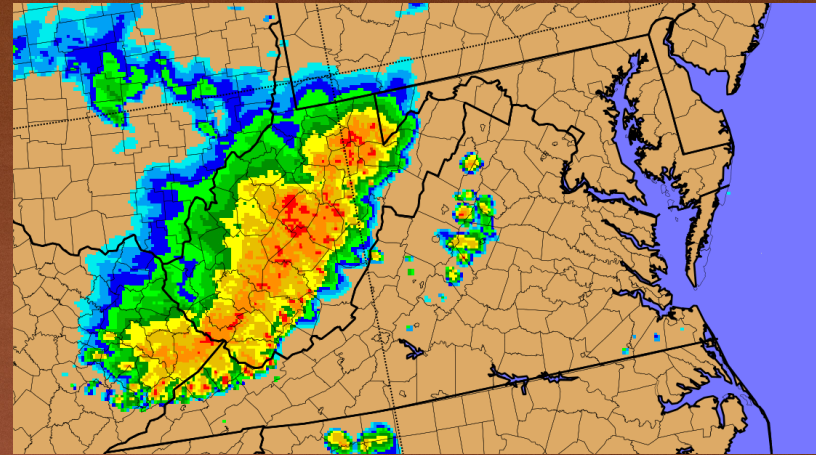


# **FV<sup>3</sup>-powered Global-to-Regional Modeling at GFDL and Beyond**



**Lucas Harris, S-J Lin, Shannon Rees,  
Linjiong Zhou, Rusty Benson, Jan-Huey Chen,  
Kun Gao, Andy Hazelton, Bill Stern,  
and the GFDL FV<sup>3</sup> team**

**Modeling, Analysis, Predictions, and Projections Webinar  
13 March 2017**



**PRINCETON  
UNIVERSITY**

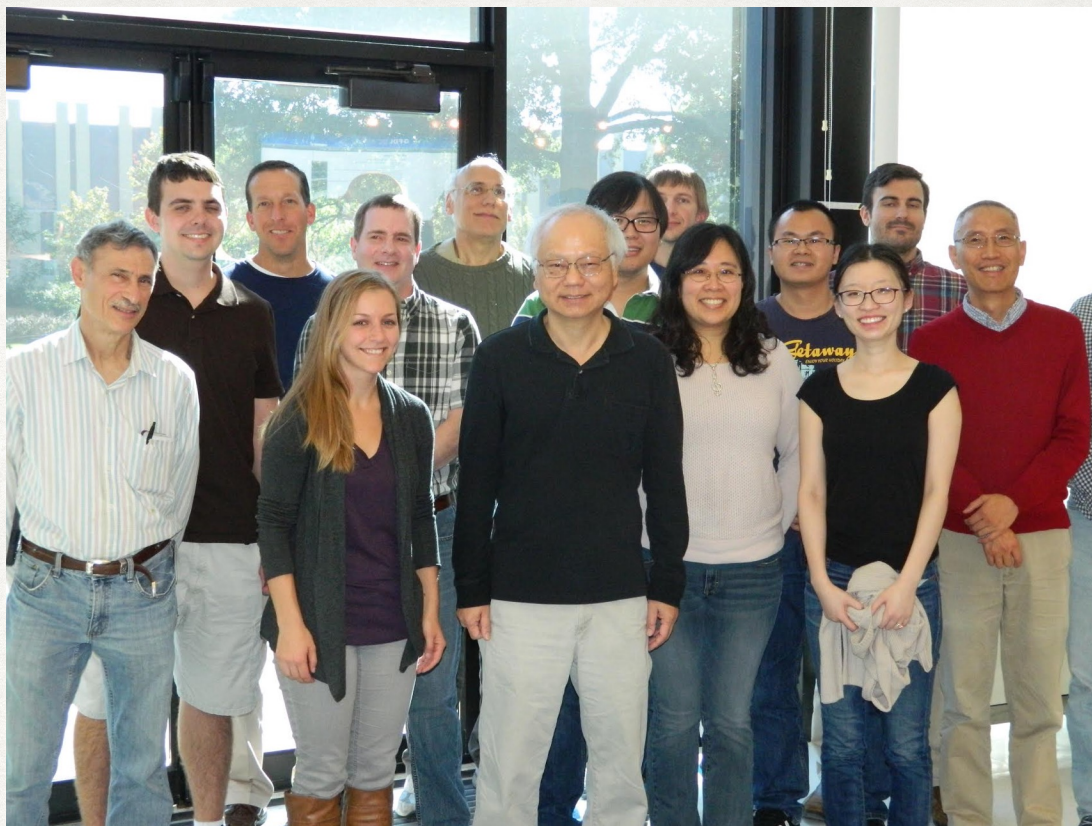


**UCAR**

UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH

Engineered to Make a Difference

# The GFDL FV<sup>3</sup> Team



S-J Lin, Team Leader  
Rusty Benson, Lead Engineer  
Morris Bender Princeton Univ.  
Jan-Huey Chen UCAR  
Xi Chen Princeton Univ.  
Kun Gao Princeton Univ.

Lucas Harris NOAA/GFDL  
Andy Hazelton Princeton Univ.  
Zhi Liang NOAA/GFDL  
Tim Marchok NOAA/GFDL  
Matt Morin Engility  
Bill Putman NASA/GSFC

Shannon Rees Engility  
Bill Stern UCAR  
Bao Xiang UCAR  
Weiye Yao Princeton Univ.  
Ming Zhao NOAA/GFDL  
Linjiong Zhou Princeton Univ.

# WHAT IS FV<sup>3</sup>? FV<sup>3</sup> IS:



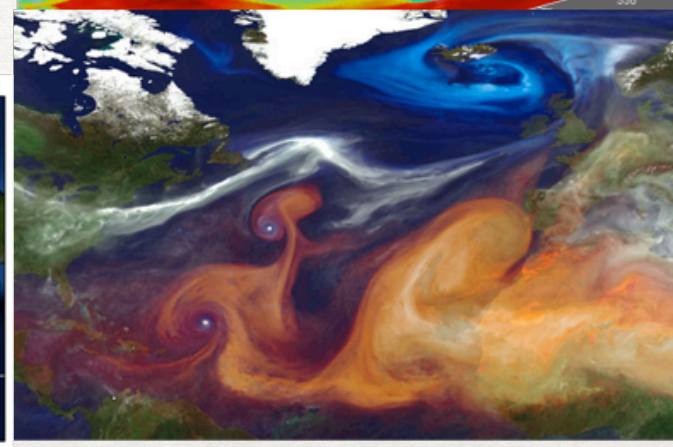
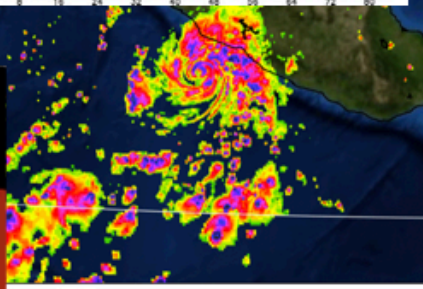
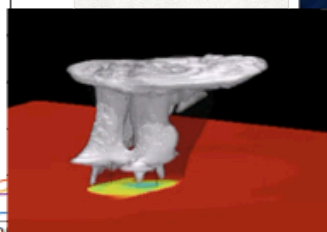
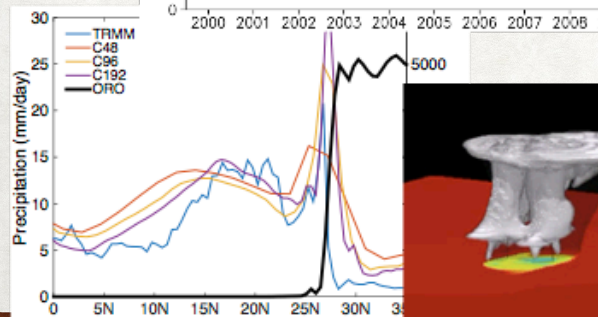
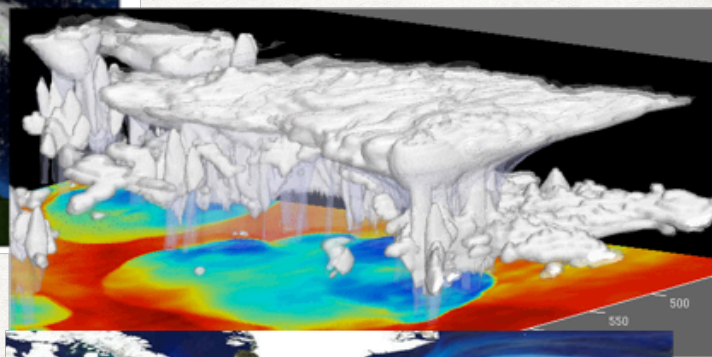
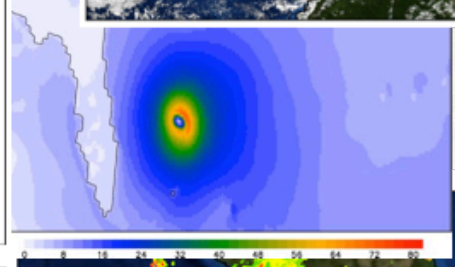
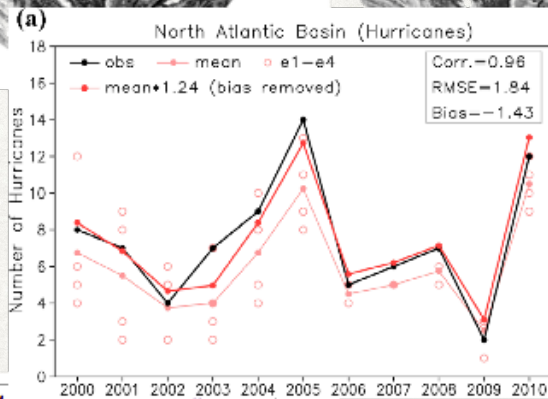
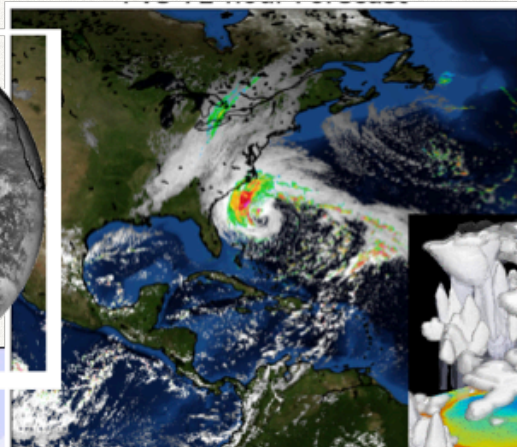
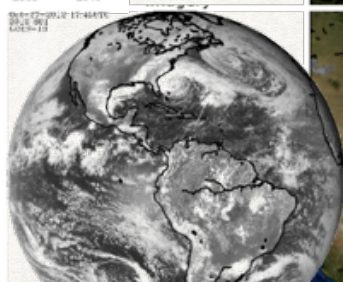
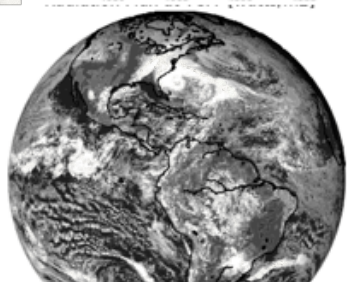
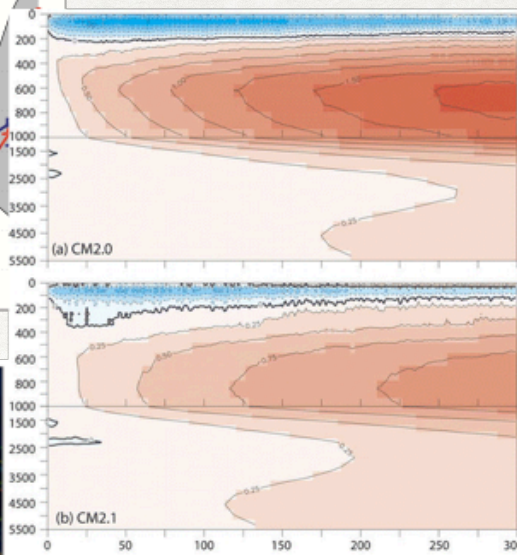
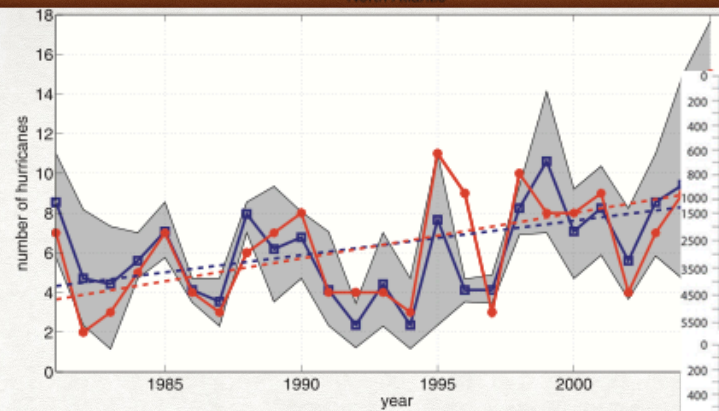
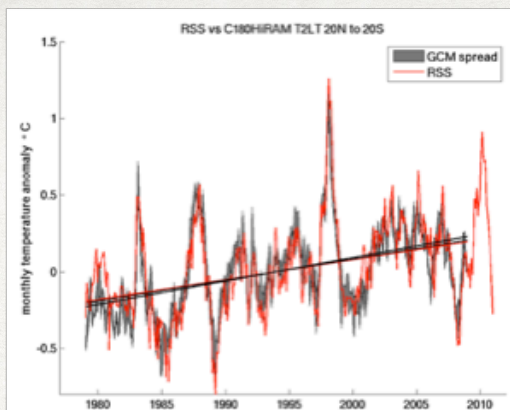
- **Fully finite volume!** Flux divergences + vertical Lagrangian + integrated PGF with excellent advection, nonhydrostatic option, and rigorous thermodynamics

But...

FV<sup>3</sup> is just a dynamical core  
not a model itself

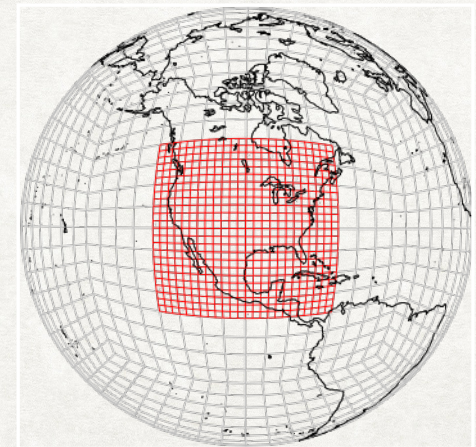
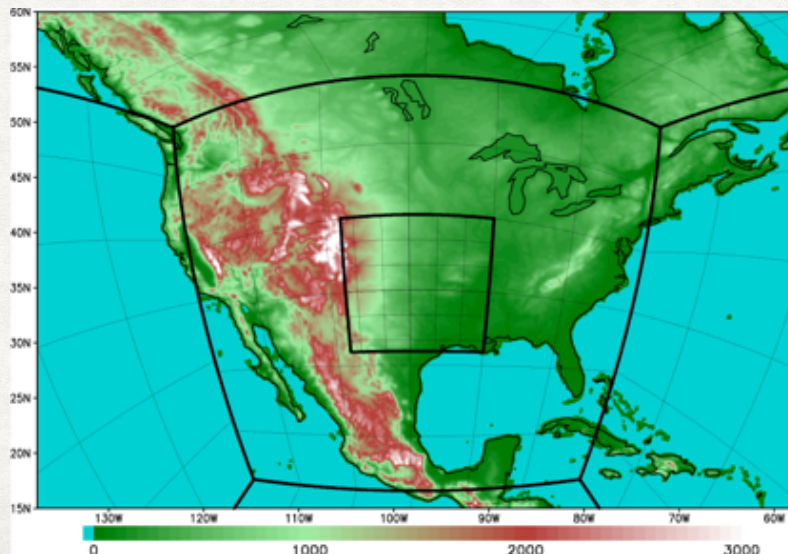
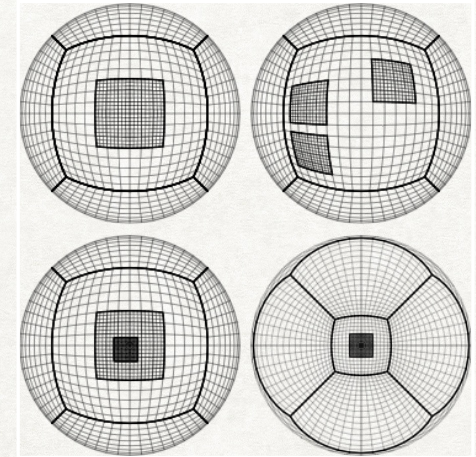
Needs physics, land model and ocean  
to be a complete model

- **Proven** effective at all scales. Maintains the large-scale circulation while accurately representing mesoscale and cloud-scale
- **Popular!** FV<sup>3</sup> the global core of choice for NOAA and NASA; predecessor FV standard in CESM and GEOS-CHEM community models, with FV<sup>3</sup> coming soon



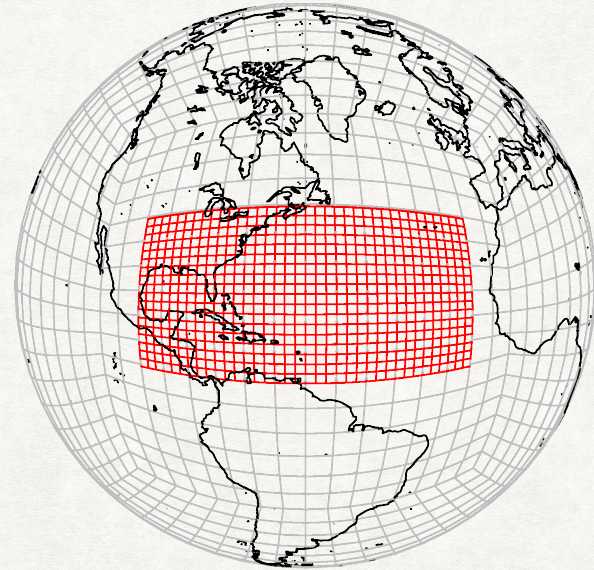
# TWO-WAY NESTING IN FV<sup>3</sup>

- **Simultaneous** coupled, consistent global and regional solution. **No waiting for a regional prediction!**
- Different grids permit different parameterizations and timesteps; **doesn't need a "compromise" for high-resolution region**
- **Flexible!** Great possibilities for combining nesting and stretching.

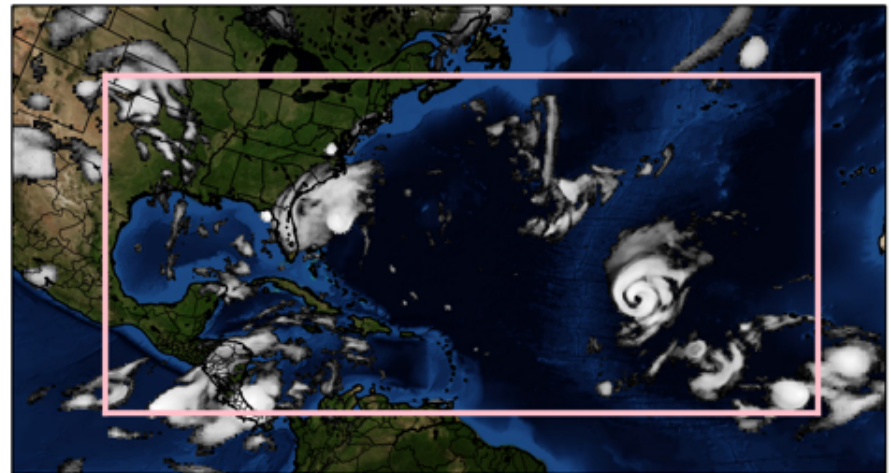


# NESTED-GRID HIRAM SUBSEASONAL FORECASTS

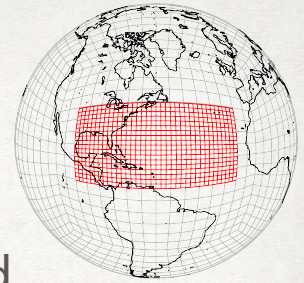
- HiRAM 4: FV<sup>3</sup> and AM2 physics + GFDL six-category microphysics and UW/GFDL double-plume convection
- Subseasonal forecasts:  
Chen & Lin (2012, 2013) seasonal frozen SST anomalies methodology
- 5-member perturbed-physics  
30-d forecast ensemble  
from 1<sup>st</sup> of each month



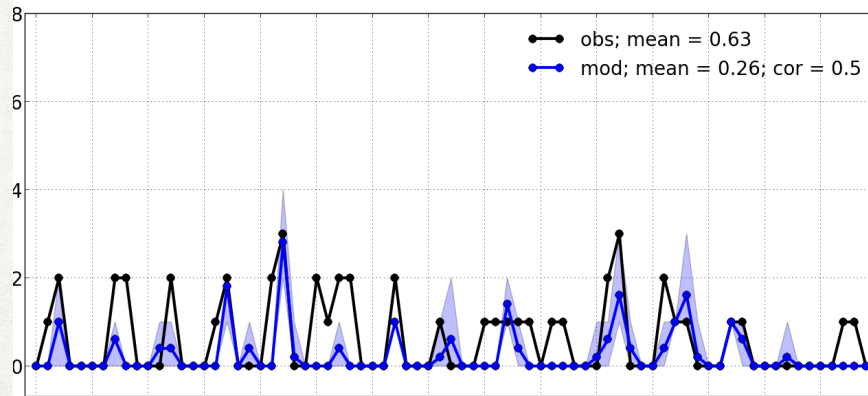
2015-08-26 13:00:00



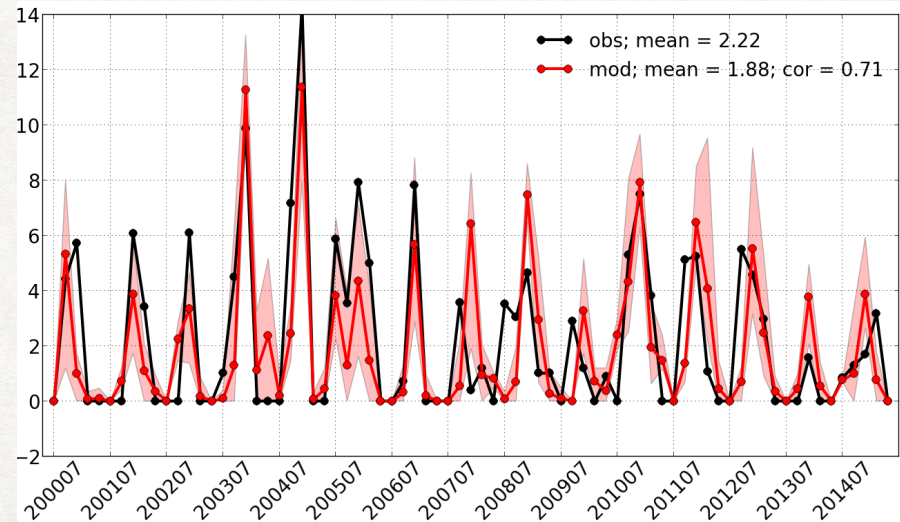
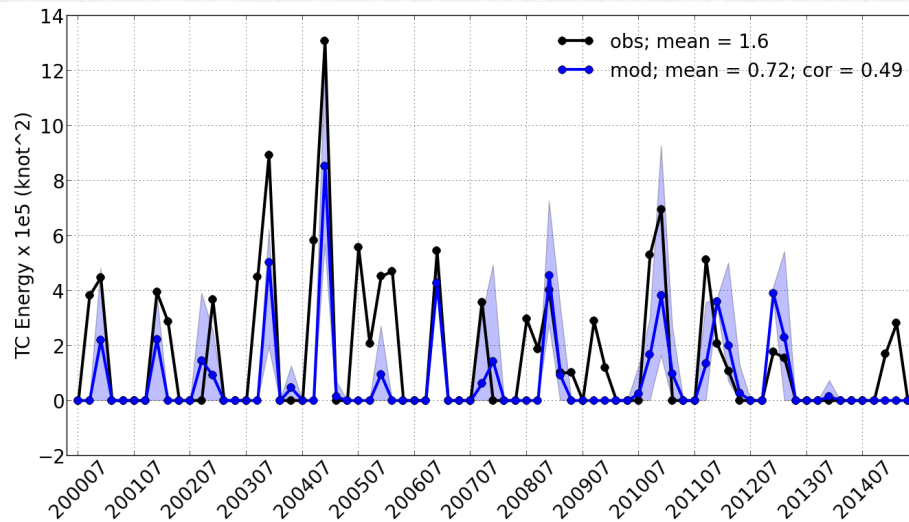
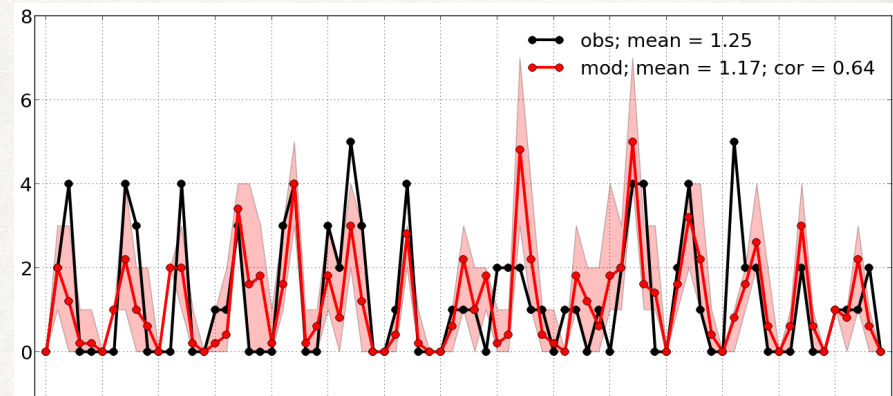
# HIRAM SUBSEASONAL FORECASTS 2000–2015 NORTH ATLANTIC MAJOR HURRICANES



25 km Uniform



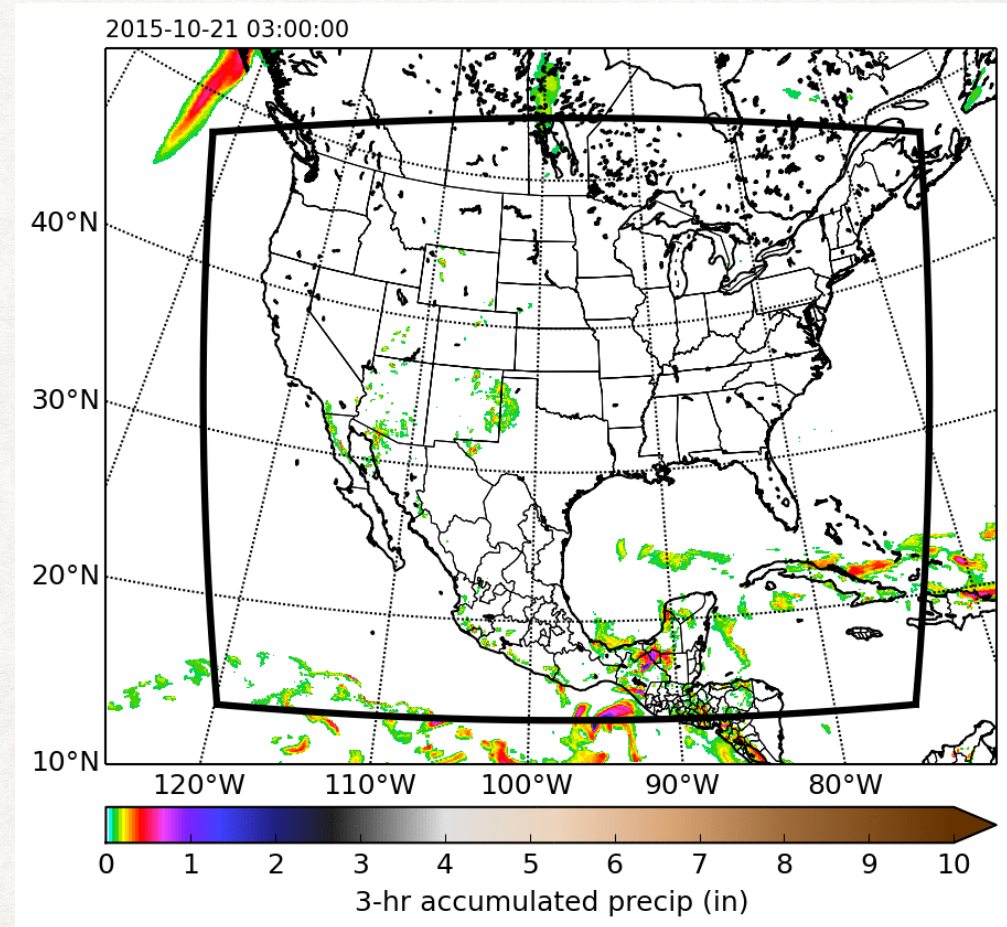
8 km Nested



Courtesy of Kun Gao

# 3-KM NESTED fvGFS

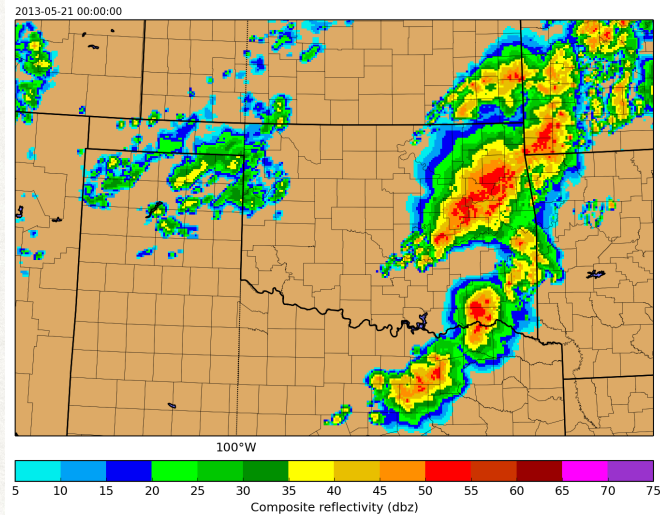
- fvGFS: FV<sup>3</sup> coupled to GFS physics
  - Prototype and proof-of-concept for next-generation GFS and unified global-to-regional forecast model
  - Simple GFS microphysics replaced with GFDL six-category scheme
- CONUS nest to 3 km for severe storm forecasts
- Atlantic nest to 2km for hurricane forecasts



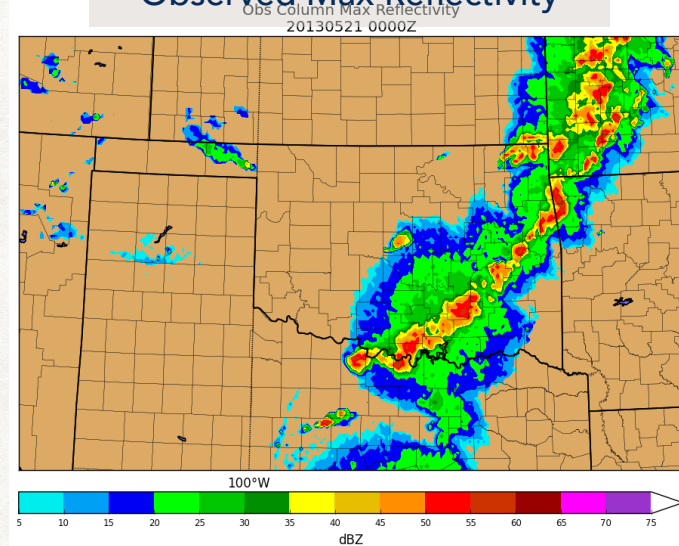
# SEVERE CONVECTION IN fvGFS

2013 MOORE OUTBREAK FORECAST INITIALIZED 00Z 18 MAY (72 HOUR LEAD)  
TUNED SAS-SHALLOW AND PBL, NO DEEP CONVECTION

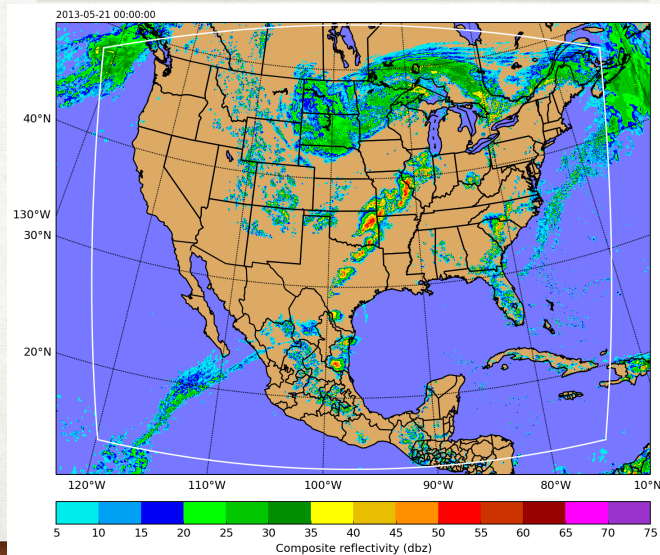
fvGFS Max Reflectivity



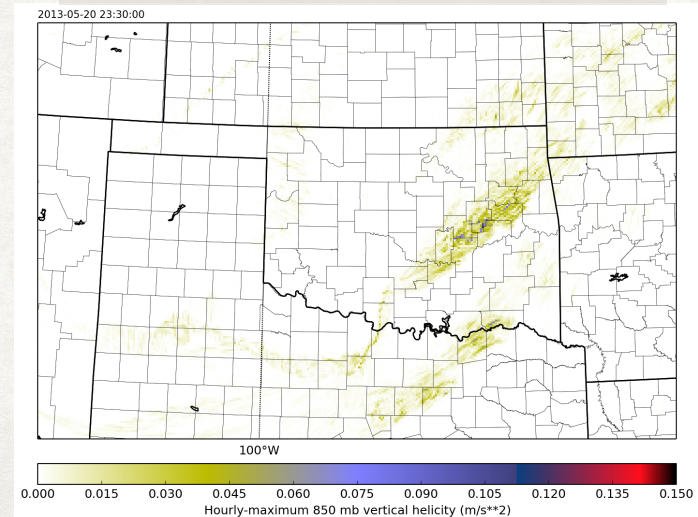
Observed Max Reflectivity



fvGFS CONUS Max Reflectivity

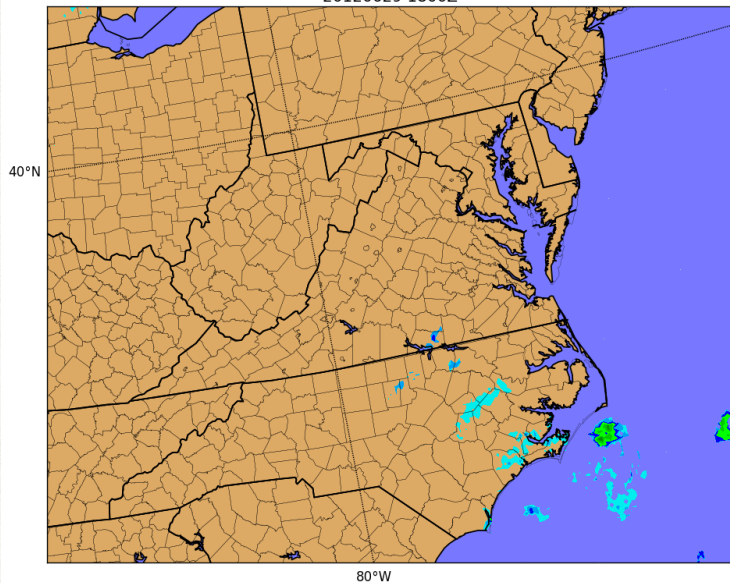


fvGFS 850 mb Updraft Helicity



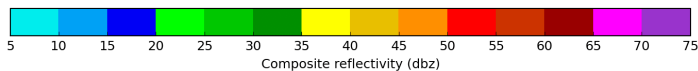
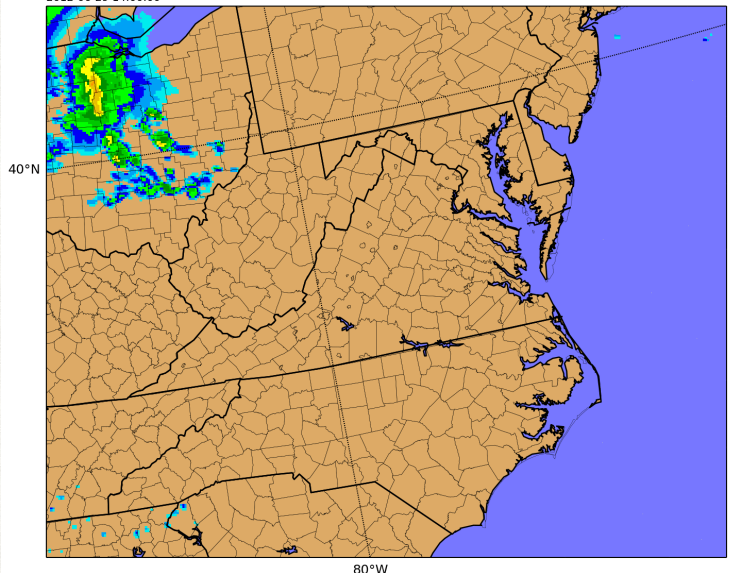
## Observed Composite Reflectivity

20120629 1800Z



## fvGFS Composite Reflectivity (-4 hr)

2012-06-29 14:00:00



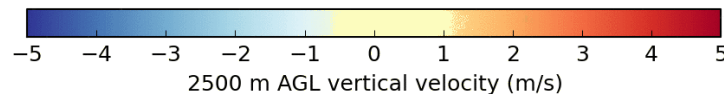
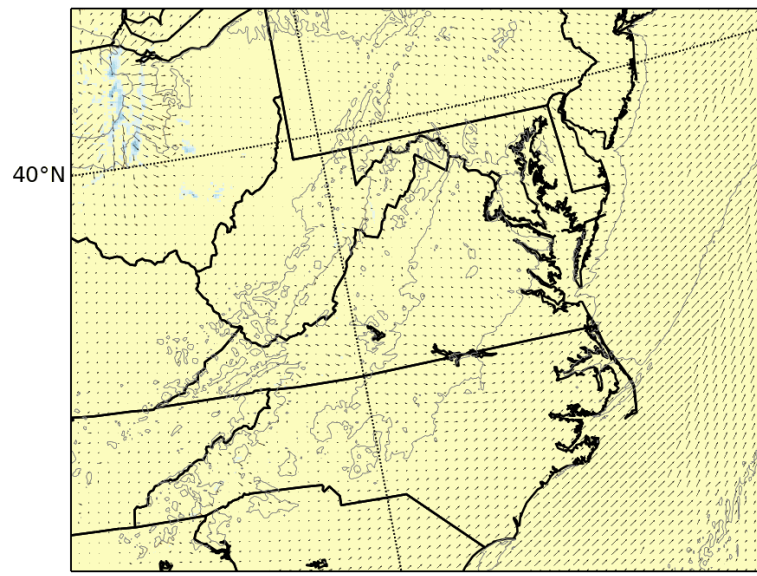
## SEVERE CONVECTION IN fvGFS

**2012 DERECHO FORECAST INITIALIZED 00Z  
27 JUNE (72 HOUR LEAD)**

**TUNED SAS-SHALLOW AND PBL,  
NO DEEP CONVECTION**

## fvGFS w2500, lowest-level winds, T

2012-06-29 14:00:00

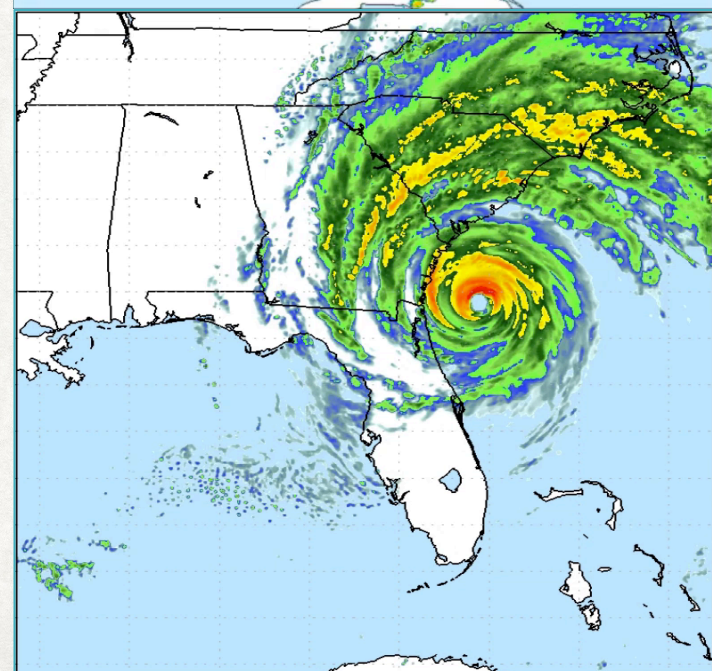
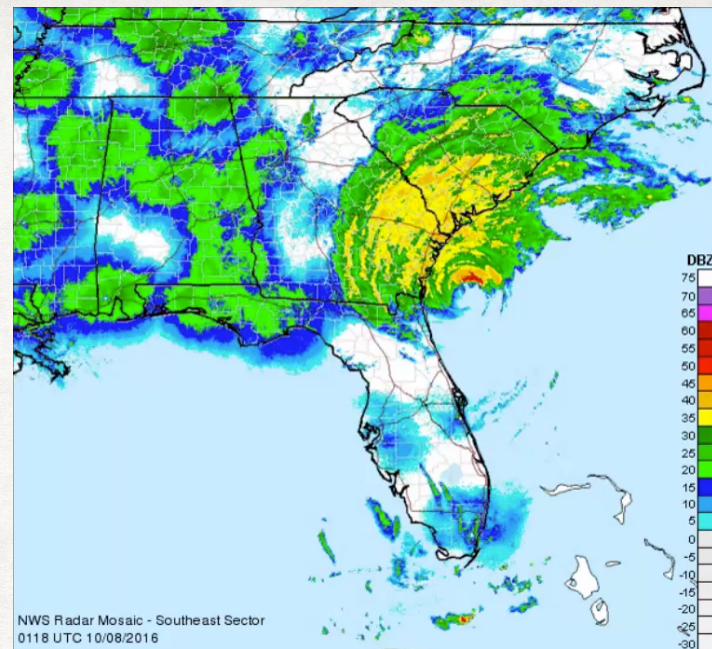
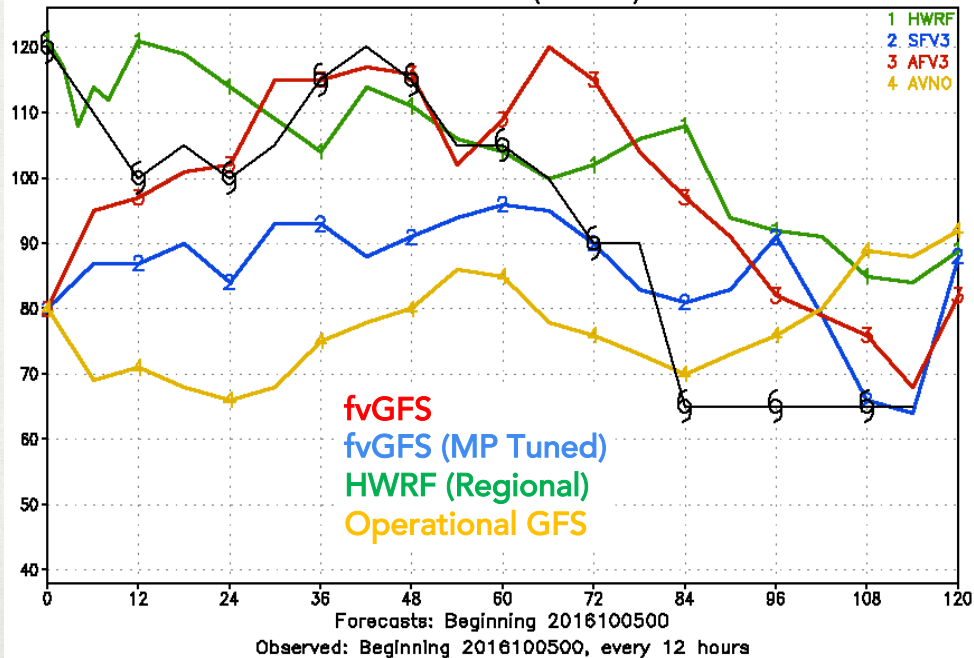


# HURRICANE MATTHEW

INITIALIZED 5 OCT 2016  
DEEP CONVECTION ON  
TUNED SAS-SHALLOW AND PBL

Courtesy Andy Hazelton and Morris Bender

2016 Tropical Cyclone Tracks  
Storm: AL1416 (MATTHEW)

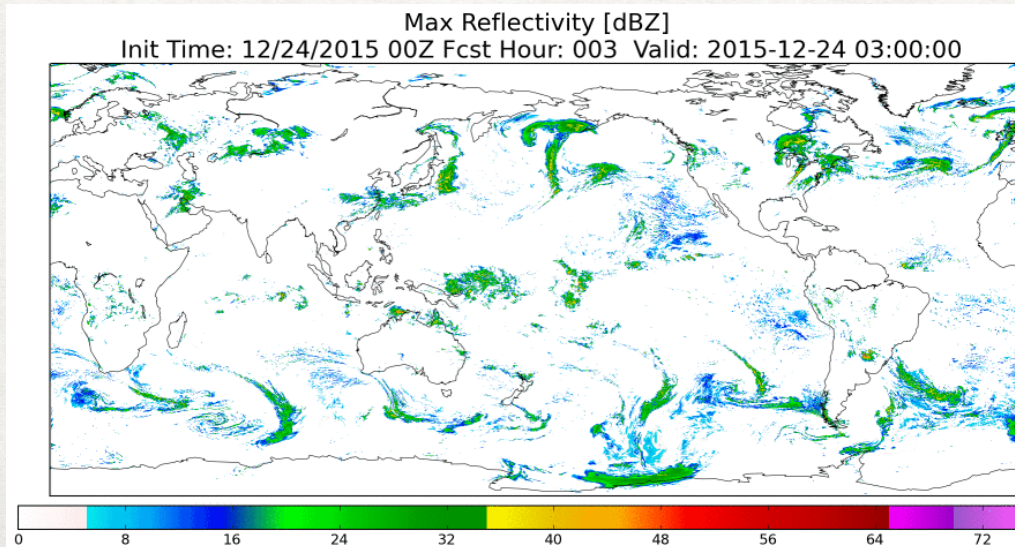


# GLOBAL CONVECTION-RESOLVING FORECASTING

GEOS-5 Modeled Clouds at 3.5km Global Resolution  
for January 2, 2009

NASA/GSFC:  
Dr. Bill Putman  
Dr. Max Suarez  
Greg Shirah

2009: NASA GEOS-5 at  
3.5 km global resolution



2017: GFDL fvGFS at  
3-km global resolution

45 mins/day with 18.5K processors

Courtesy S-J Lin and Shannon Rees

# PLANS FOR GLOBAL-TO-REGIONAL MODELING

- fvGFS: Working towards real-time 3-km system for HWT Spring Experiment
  - Improvements to land model, microphysics, and forecast diagnostics
  - Longer term: considering Thompson MP, YSU PBL, UW/GFDL Convection, etc.
- HiRAM & AM4: Bring grid refinement into next GFDL model
  - Convection-permitting (and resolving?) seasonal and longer simulations
- NCEP & AOML FV<sup>3</sup>-powered models:
  - 3-km NAM physics
  - Moving nested grids for next-generation HWRF
- NASA: 1.5-km GEOS forecasts coming soon
  - 3-km, year-long global nature run planned

# **ADDITIONAL SLIDES**

## PLANS FOR CONVECTION-RESOLVING fvGFS APPLICATIONS

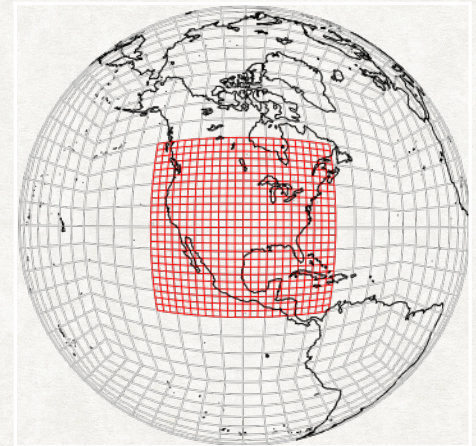
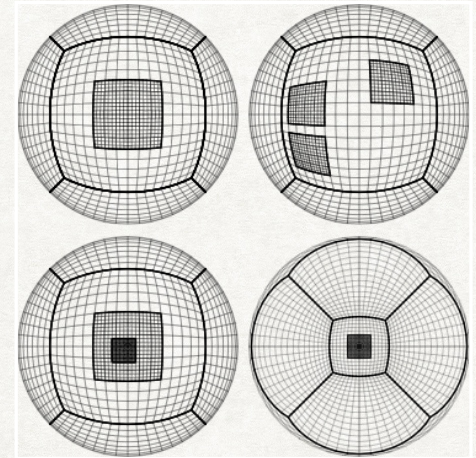
- Thompson, Ferrier, or M-G Microphysics (collaboration with OU-CAPS and EMC)
- YSU, EDMF, or M-Y-type PBL
- Higher-resolution land model inputs
- Two fvGFS variants for the 2017 HWT Spring Experiment:
  - GFDL: fvGFS with GFDL MP
  - OU-CAPS: fvGFS with Thompson MP
- FV<sup>3</sup>-powered NAM and HWRF planned at EMC and AOML
- Convection-resolving and convection-permitting GFDL HiRAM/AM4 to continue

[fvGFS is still improving! Stay tuned for further updates.](#)

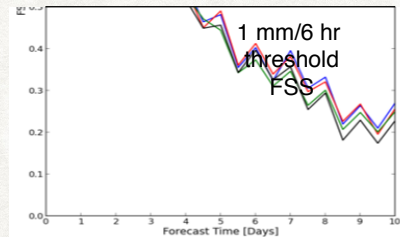
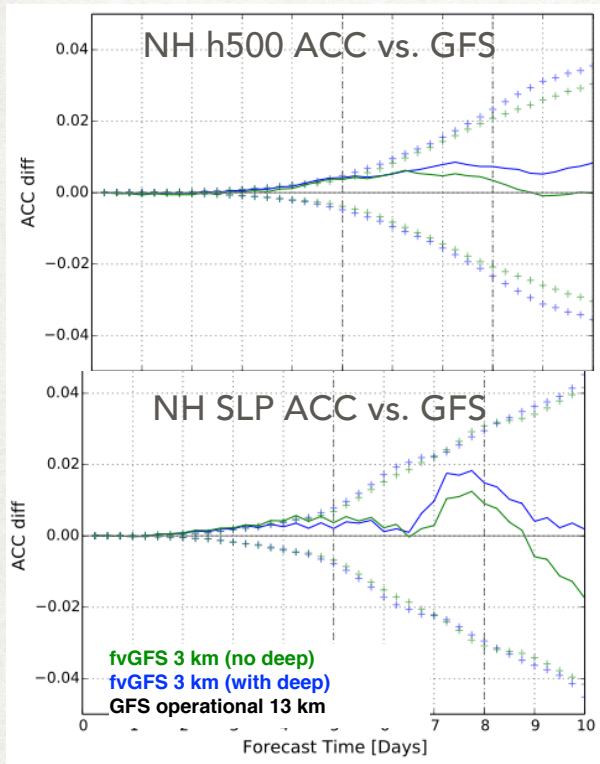
Special thanks to collaborators and others at CAPS, EMC, SPC, NSSL, AOML, NASA, and Harvard U.

# TWO-WAY NESTING IN FV<sup>3</sup>

- Correct inflow/outflow BCs “baked-in” by FV<sup>3</sup> upwinding fluxes
- Concurrent nesting permits both domains to be run simultaneously
- Two-way updating of winds,  $w$ , and temperature consistent with finite-volume discretization
- Trivial mass conservation by not updating the mass field



# 2015 HINDCAST SKILL IN NESTED fvGFS



CONUS Precipitation Fractions Skill Score  
12 km neighborhood for nested,  
40 km for uniform

fvGFS 13 km  
fvGFS 3 km (no deep)  
fvGFS 3 km (w/ deep)  
GFS 13 km

